Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Mapping Six Decades of Research and Innovation in Cardiac Electrophysiology: A Historical Scientometrics Analysis

Oscar Andrés Alzate Mejía[1,2], Foday Tejan Mansaray[3], Ornella Fiorillo-Moreno[4,5], Johana Patricia Galván-Barrios[6]

[1]Facultad de Ciencias para la Salud, Universidad de Manizales, Manizales, Caldas, Colombia; [2]Facultad de Salud, Universidad Autónoma de Manizales, Manizales, Colombia; [3]Department of Medicine, Connaught Hospital, Freetown, Sierra Leone; [4]Research Department, Clínica Iberoamérica, Barranquilla, Colombia; [5]Research Department, Clínica El Carmen, Barranquilla, Colombia; [6]Biomedical Scientometrics and Evidence-Based Research Unit, Department of Health Sciences, Universidad de la Costa, Barranquilla, Colombia

Correspondence: Foday Tejan Mansaray, Connaught Hospital, Freetown, Sierra Leone, Email foday.tejam@gmail.com; Johana Patricia Galván-Barrios, Universidad de la Costa, Barranquilla, Colombia, Email jgalvan11@cuc.edu.co

Background: Cardiac electrophysiology research has expanded rapidly, yet its global distribution, collaborative dynamics, and thematic evolution have never been quantified across the full history of the field. Mapping these patterns is crucial for guiding funding and designing impactful studies.

Methods: A scientometrics analysis was conducted on articles indexed in Scopus, Web of Science, and PubMed (1959–2025). After screening, 3766 peer-reviewed papers were analyzed. Publication trends, citation-based indicators (h-index, which reflects productivity and impact; g-index, which highlights highly cited work; and m-index, which adjusts for time), journal quartiles, World Bank income-levels, and WHO regions were quantified. Co-authorship networks mapped institutional and national partnerships, while text-mining tracked keyword trajectories to identify emerging research fronts.

Results: Annual publications increased from 3 in 1959 to 268 in 2021. Articles averaged six co-authors, with 25% showing international collaboration. High-income countries produced 86.7% of output and dominated journals' impact (mean h-index = 155). In contrast, lower-middle-income nations contributed only 1.9%. The University of California and the United States were central collaboration hubs, while Africa and Latin America remained peripheral. Keyword analysis showed a shift from pharmacology and in-vitro biophysics to newer areas such as implantable devices, artificial intelligence–guided risk scoring, and stem cell–based models. Emerging concepts such as Bayes theorem (for probabilistic modeling) and quantitative trait locus (for linking genetics to arrhythmia risk) are beginning to appear, though still scarcely represented. Cross-continental papers received the highest citation density.

Conclusion: Cardiac electrophysiology knowledge is concentrated in high-income regions and in teams with strong collaboration. This map highlights geographic blind spots and emerging themes, offering a practical guide for building north–south consortia, focusing on neglected pathologies, and investing in artificial intelligence and stem-cell–based strategies likely to drive the next breakthroughs.

Keywords: cardiac electrophysiology, electrophysiology, bibliometrics, research, knowledge discovery

Introduction

Cardiac electrophysiology (CEP) links fundamental bioelectric mechanisms to the clinical management of arrhythmias that jeopardize life and strain health-care systems.[1] Disruptions in ion-channel kinetics or cell–cell coupling can destabilize action-potential propagation, culminating in atrial fibrillation, ventricular tachycardia, and sudden cardiac death, entities responsible for roughly one in six cardiovascular fatalities and substantial global expenditure.[2] Accordingly, a precise understanding of how CEP knowledge is generated, disseminated, and applied is pivotal for directing research investment and refining patient care.

Received: 7 May 2025
Accepted: 20 September 2025
Published: 25 September 2025

Scientific activity in CEP has accelerated since the late 1950s, propelled by three converging developments.[3] First, high-resolution electro-anatomical mapping and catheter ablation have redefined rhythm management, converting many open-surgical procedures into percutaneous interventions.[3] Second, biological innovations, most notably induced pluripotent stem cell-derived cardiomyocytes, have enabled interrogation of arrhythmogenic mechanisms at subcellular resolution.[3,4] Third, computational advances now leverage artificial intelligence to detect electrocardiographic signatures invisible to human observers and predict arrhythmic risk at scale.[3,4] These advances have produced a heterogeneous body of evidence that spans in-vitro ion-channel studies, translational animal work, multicenter trials, and international guidelines.[4]

Despite this productivity, the literature has not been synthesized quantitatively. Narrative reviews and consensus statements capture qualitative insights but cannot rank productivity, benchmark impact, or highlight neglected topics.[5,6] Scientometrics provides that quantitative lens, employing bibliometric indicators and network analysis to measure output, collaboration, and thematic evolution.[7] Yet, to our knowledge, no comprehensive scientometrics appraisal has mapped CEP across its physiological, biological, and clinical axes worldwide.

This gap hampers strategic decision-making.[8] Funding bodies and policy makers lack objective data to prioritize high-yield or under-studied areas;[9] early-career researchers cannot easily identify emerging niches or suitable collaborators;[9] and duplication of effort persists, delaying translation into practice.[9] Without a macro-level perspective, disparities widen: high-income nations dominate publication and citation counts, whereas lower-income regions remain under-represented, even where disease burden is high.[10]

The aim of this study was to conduct a comprehensive scientometrics analysis of global historical scientific output on CEP, mapping temporal growth, bibliometric impact, collaboration networks, and emerging thematic trends, to identifying knowledge gaps and geographic or socioeconomic disparities that can guide strategic decisions in research, funding allocation, and cardiovascular health policy.

To date, no study has systematically quantified geographic or thematic disparities in CEP research. By leveraging the broad coverage of Scopus, Web of Science, and PubMed, this study provides the first comprehensive scientometrics map capable of documenting not only historical advances but also the inequities that shape knowledge production in the field.

Methods

Study Design

Scientometrics analysis employs quantitative approaches, grounded in mathematical and statistical techniques, to evaluate the volume and influence of research publications. This methodology facilitates the detection of temporal trends, collaborative networks, and the evolution of research themes.[7,11]

Source Database

A comprehensive documentary search was conducted in Scopus, Web of Science (All Collection), and PubMed, three of the largest repositories of peer-reviewed literature, encompassing the field's most influential journals and publications.[12]

Search Design

A comprehensive search was carried out to identify all available publications on the topic, taking into account MeSH terms and synonyms. For this analysis, the MeSH descriptor "Cardiac Electrophysiology" (Unique ID: D054849) and its synonym "Cardiac Electrophysiologies" were employed. To ensure the inclusion of the most relevant literature, a specific search strategy was carefully developed and applied: TITLE-ABS-KEY("Cardiac Electrophysiology") OR TITLE-ABS-KEY("Cardiac Electrophysiologies"). The field tags in this equation were modified to ensure its reproducibility across all databases (Topic in Web of Science; and Title/Abstract in PubMed).

Records were eligible when they met both of the following criteria: A) Peer-reviewed articles published in regularly issued scientific journals; and B) Documents centered on analyzing, discussing, investigating, summarizing, or exploring the electrical activity and characteristics of the heart, myocardium, and cardiomyocytes.

Documents were excluded if they met at least one of the following conditions: A) They were conference proceedings, book chapters, book series, full books, errata, data papers, conference reviews, or retracted publications; B) Ther were publications still in press or C) Lacked essential bibliographic information (eg, author names, journal title, or correspondence details). Exclusion criteria were applied systematically during the screening process.

Publications in English, Portuguese, or Spanish were considered, as were papers in other languages provided, they included an abstract in any of these three languages and met all inclusion criteria without violating any exclusions. No temporal limits were imposed because the analysis aimed to provide a historical overview.

Data Collection

The literature search extended through 9 April 2025 and was restricted to the "journals" source type. Two investigators (OAAM and JADV) executed an initial manual screening in Microsoft Excel. Duplicate records across databases were identified and removed through a two-step process: first, automated matching of Digital Object Identifiers (DOIs) and titles in Excel; second, manual verification by two independent reviewers to resolve discrepancies. A second investigator pair (JADV and OFM) subsequently performed data-curation and harmonization of the definitive dataset.

Documents labelled "article" corresponded to primary empirical studies, whereas the "review" class encompassed narrative, scoping, systematic, and meta-analytic syntheses. Although the eligibility criteria stipulated the inclusion of peer-reviewed outputs only, virtually all serials indexed in the chosen databases are subject to peer review as a prerequisite for indexing. Nonetheless, items tagged as "Editorial" or "Letter" may receive only editorial scrutiny and thus were excluded from the peer-reviewed corpus.

Potential biases related to database indexing and language restrictions were also considered: while our inclusion of Scopus, Web of Science, and PubMed maximized coverage, we recognize that regional or non-English journals may remain underrepresented. These measures enhanced transparency and helped control for systematic bias in the dataset.

Data Analysis and Visualization

We examined historical research trends using two main approaches: bibliometrics and network analysis.[13,14] Quantitative metrics came from the bibliometrix package in R (v 4.3.1),[15] while simple counts and percentages were compiled in Microsoft Excel.

For the geographic view, countries were sorted by World Bank income groups,[16] low, lower-middle, upper-middle, and high, and by World Health Organization's regions: Africa, Americas, South-East Asia, Europe, Eastern Mediterranean, and Western Pacific.[17]

To better understand the impact of scientific production, we calculated the journals h-index, m-index, and g-index, along with citation counts.[18] The h-index reflects both the quantity and influence of published articles through citation analysis.[18] The m-index adjusts this measure over time, giving a sense of the author's consistent impact.[18] The g-index adds another layer, emphasizing highly cited papers by summarizing citation distribution in a way that highlights the overall influence of a researcher's most impactful work.[18]

We also examined how scientific production has evolved over time. Lotka's law was used to explore how publications are distributed among authors and across institutions and countries.[18] Lastly, we mapped out collaboration networks between countries and institutions, offering a clearer picture of how global research efforts are interconnected.

Keyword trajectory validation was performed by analyzing frequency trends across consecutive five-year intervals, confirming that observed trajectories reflected consistent temporal patterns rather than isolated occurrences. To further ensure accuracy, two independent reviewers harmonized extracted keywords, resolving discrepancies by consensus. This multi-step validation enhanced the reproducibility and reliability of thematic evolution analyses.

Results

General Characteristics

A total of 3766 articles were selected after applying the inclusion and exclusion criteria. Considering that the first publication was recorded in 1959, the analysis window spanned 66 years (1959–2025). Scientific production was predominantly composed of original research articles (74.19%; n=2794), followed by review articles (18.59%; n=700). The average number of co-authors per article was six, with an international collaboration rate of 25.09% (Table 1).

Regarding the scientific evolution since the 1950s, annual publication output was initially modest, beginning with very few publications. However, a notable growth trend was observed over time, peaking in 2021 (Figure 1). In contrast, the citation count was significant from the earliest years, displaying considerable fluctuations over time and reaching its peak in 2010 (Figure 1).

Applying Lotka's Law revealed that 79% of authors had published only one document, while 12% had authored two publications. This pattern reflects the principle of Lotka's law, where the majority of authors contribute a single publication, while a minority sustains the field through repeated contributions. In cardiac electrophysiology, this underscores the presence of a relatively small but highly prolific core of researchers who drive long-term knowledge generation.

Scientific Output by Geographic Region and Income Levels

Regional data were missing for about one paper in four, leaving 2919 articles to analyze. Europe led the field with 1242 publications (42.5%), followed closely by the Americas with 1190 (40.8%). The Western Pacific contributed 403 papers (13.8%). In contrast, the Eastern Mediterranean, South-East Asia, and Africa combined produced fewer than a hundred articles (n=50; 1.7%, n=29; 1.0%, and n=5; 0.2%, respectively).

Income-group data, also available for 2919 publications, revealed a pronounced dominance of high-income countries (n=2530/2919; 86.7%). Upper-middle-income nations produced 11.4% (n=334) and lower-middle-income nations 1.9% (n=55) of the output; no records originated from low-income settings.

Country of affiliation was reported for 2939 articles (78.1%). Five nations generated two-thirds of the global literature: the United States led by a considerable margin (n=993/2939; 33.8%), followed by the United Kingdom (n=284; 9.7%), Germany (n=231; 7.9%), China (n=215; 7.3%), and Canada (n=113; 3.8%). Together, these countries accounted for 62.5% of all articles with identifiable provenance.

Table 1 General Characteristics of Global Scientific Output in Cardiac Electrophysiology Research (N = 3766)

	n	%
Article Type		
Original article	2794	74.19
Review	700	18.59
Editorial	174	4.62
Short survey	14	0.37
Letter	47	1.25
Note	37	0.98
Authors		
Authorship	13,729	–
Documents with single authorship (N = 13,729)	266	7.18
Collaboration		
Articles with single authorship	341	–
Average number of co-authors per article	6	-
International co-authorship	-	25.09
Average article age (years)	7	-
Average citations per document, (mean) SD	25	60.6
Keywords	6582	-
Scientific sources	1044	-
H-index key sources, (mean) SD	151.1	134.9

Abbreviation: SD, Standard Deviation.

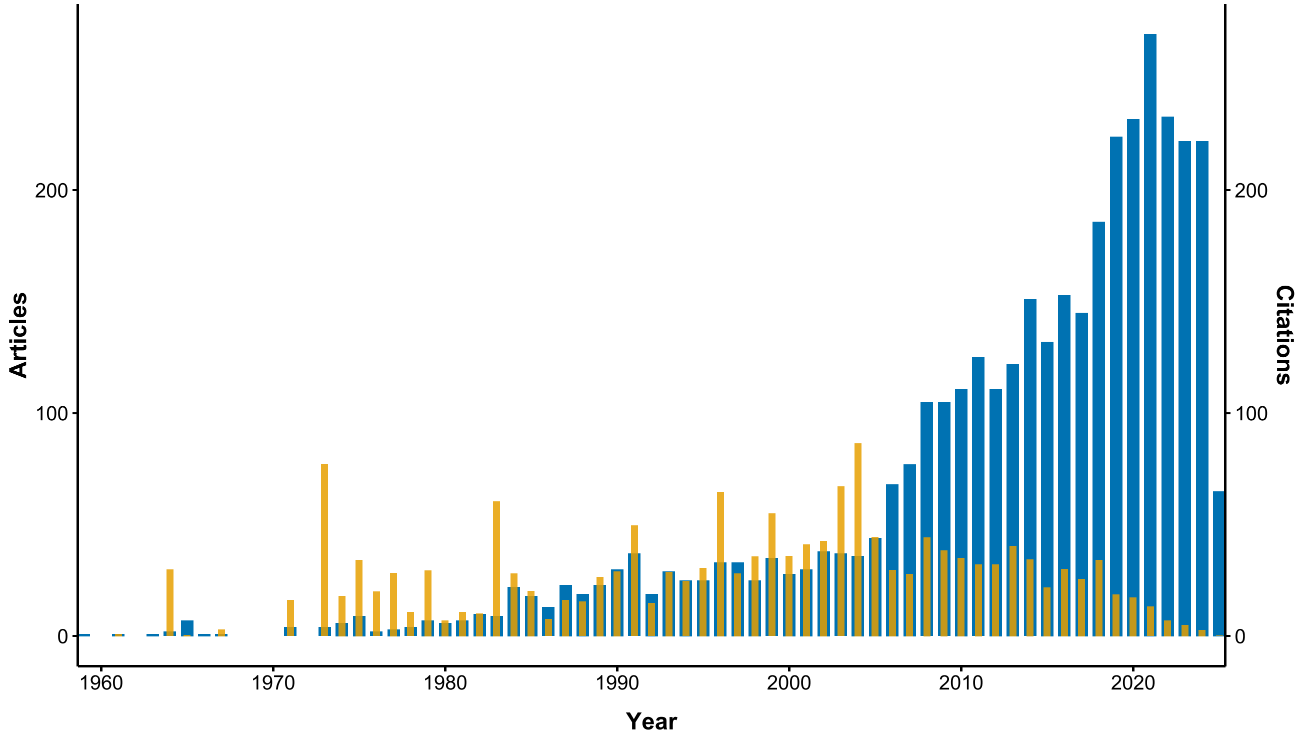

Figure 1 Annual progression of global research on CEP since 1960. Blue indicates the number of publications per year, and yellow represents the mean citations accrued per article each year.

Americas exhibited the greatest concentration in top-tier outlets: 787 of 1166 articles appeared in Q1 journals (67.5%), whereas only 23 (2%) reached Q4. Europe displayed a similar although slightly less pronounced profile, with 58.8% of its 1206 articles published in Q1 and 7.1% in Q4. The Western Pacific region showed a more even spread, allocating 49.2% of its 388 papers to Q1 and 31.4% to Q2. Regions with lower publication volumes revealed heterogeneous patterns: in the Eastern Mediterranean, merely 14 of 47 articles (29.8%) were classified as Q1 and almost one-third (31.9%) fell into Q4, whereas South-East Asia divided its 28 records almost evenly between Q1 (50%) and Q3–Q4 combined (35.7%). The African dataset was too small for robust inference (n=3, two of which were Q1).

High-income countries published 1570 of 2474 papers in Q1 journals (63.5%) and relegated only 4% to Q4. Upper-middle-income nations achieved 40.1% Q1 representation (n=126/314) but saw nearly one-third of their output in Q3–Q4 venues (30.9%). Lower-middle-income countries, with just 50 analyzable records, placed 42% in Q1 and a combined 40% in Q3–Q4, underscoring the quality gap that accompanies economic status.

Mean H-index values, calculated over the 3493 articles with non-missing metrics, reached 169.1 in the Americas and 141.9 in Europe, with corresponding mean citation counts of 30.1 and 23 per article, respectively. The Western Pacific recorded a moderate mean H-index of 123.3 and 12.4 citations, while the Eastern Mediterranean (67.2; SD 4.4), South-East Asia (100.4; SD 8.4), and Africa (75; SD 9.8) lagged substantially. When disaggregated by income, high-income countries averaged an H-index of 155.3 and 26.3, respectively. Upper-middle-income countries followed with mean values of 107.5 and 9.4, whereas lower-middle-income nations posted the lowest averages, 88.3 for H-index and 3.6 citations.

Temporal trends in scientific output and the impact of Q1–Q2 publications across geographic regions, the most prolific countries, and income groups are presented in Figure 2a–d.

Key Scientific Sources in CEP

Regarding the journals where these studies are most frequently published, Heart Rhythm stands out with the highest number of publications (n=150) (Figure 3a). However, Circulation Research has received the highest number of citations

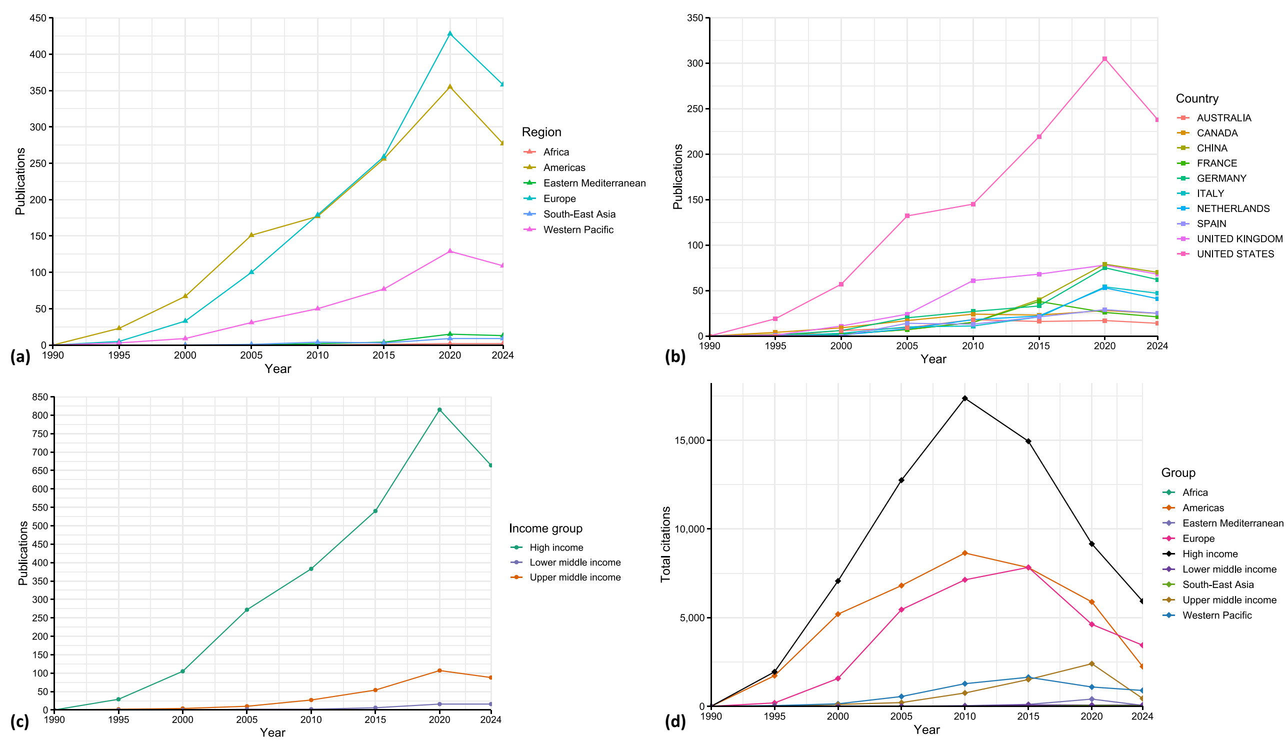

Figure 2 Evolution of global research on CEP published in Q1–Q2 journals. (**a**) Publications by geographic region. (**b**) Publications by the most prolific countries. (**c**) Publications by income group. (**d**) Total citations accrued by each income group and region.

(n=7928) (Figure 3b) and holds the highest h-index value (Figure 3c). Notably, Heart Rhythm achieved the highest values according to the g-index (Figure 3d) and m-index (Figure 3e).

In particular, American Journal of Physiology – Heart and Circulatory Physiology and Heart Rhythm have demonstrated the most significant growth in recent years, reaching their publication peaks recently, despite having relatively few publications in their early stages (Figure 3f).

Quartile information was available for 3493 publications. Almost three-fifths appeared in Q1 journals (n=2090/3493; 59.8%), while Q2 titles hosted roughly a quarter (n=851/3493; 24.4%). Q3 and Q4 outlets together accounted for just under 16% of the total (n=311/3493; 8.9% and n=238/3493; 6. %, respectively).

Scientific Collaboration Networks

Regarding international collaboration networks, the most robust network has been established by the University of California, although other prominent institutions include the University of Oxford and Johns Hopkins University (Figure 4a). In terms of country-level cooperation, the United States stands out, collaborating primarily with the United Kingdom, Asian countries such as Korea and Japan, and European countries like France (Figure 4b). Notably, there is a marked absence of collaboration with African and Latin American countries.

Historical Trends in Research Topics

Regarding research patterns and historical trends, the construction of a keyword cloud revealed that "heart arrhythmia", "heart ventricle tachycardia", "atrial fibrillation", "catheter ablation", and "long QT syndrome" have been the most frequently used keywords (Figure 5a). During the first approximately 30 years, research was primarily concentrated on topics such as "intravenous drug administration", "ouabain", "in vitro studies", "theoretical studies", and "biomedical

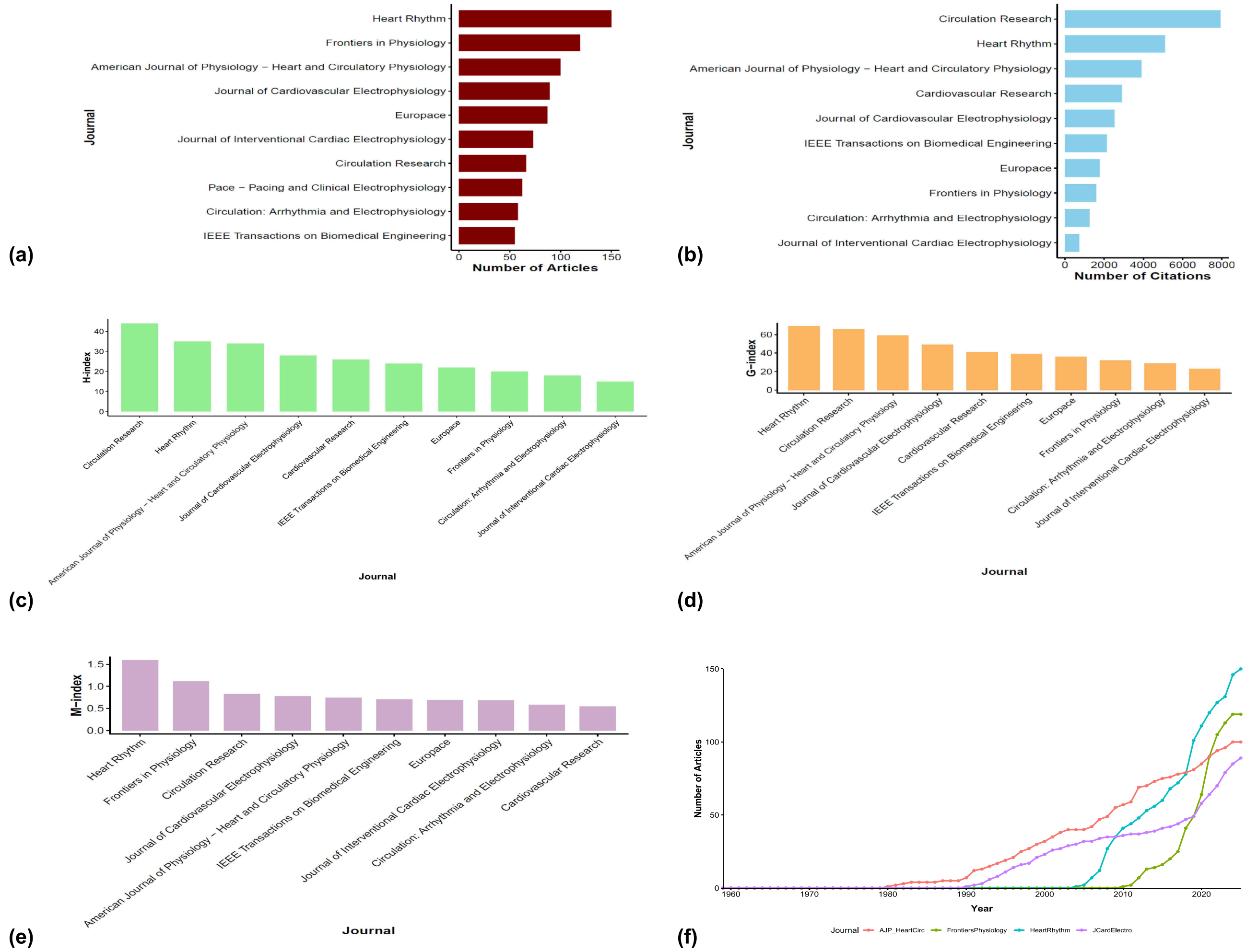

Figure 3 Key scientific sources in CEP. (**a**) Scientific sources with the greatest publication output. (**b**) Scientific sources with the highest total citation count in CEP. (**c**) Scientific journals with the highest impact measured by the h-index. (**d**) Scientific journals with the highest impact measured by the g-index. (**e**) Scientific journals with the highest impact measured by the g-index. (**f**) Editorial growth of the journals publishing the largest volume of CEP research.

engineering" (Figure 5b). In contrast, between 2000 and 2024, research has predominantly focused on "drug effect", "heart arrhythmia", and "induced pluripotent stem cells" (Figure 5c).

In the past two years, an emerging research focus on "Bayes theorem" and "quantitative trait locus" has become notable (Figure 5c). Furthermore, the construction of a thematic map revealed that research on "implantable electronic devices", "cell-derived cardiomyocytes", and "atrial fibrillations represents novel and emerging niches within the field of CEP (Figure 5d).

Discussion

This analysis reveals a research community that has matured from sporadic single-author reports to a multidisciplinary enterprise marked by a mean of six co-authors per paper and a 25% rate of international collaboration. The inflection in publication volume after 2000 parallels widespread access to three-dimensional electro-anatomical mapping and a surge in device-based therapies, suggesting that technological breakthroughs catalyze bursts of scholarly output. Although citation density peaked in 2010, the subsequent plateau indicates that additional publications do not automatically translate into higher per-article influence, underscoring the need for quality-focused rather than volume-driven dissemination strategies.[19]

The dominance of high-income regions, Europe and the Americas (essentially USA) together account for >80% of all articles, mirrors global funding inequalities and the concentration of advanced electrophysiology laboratories. Strikingly,

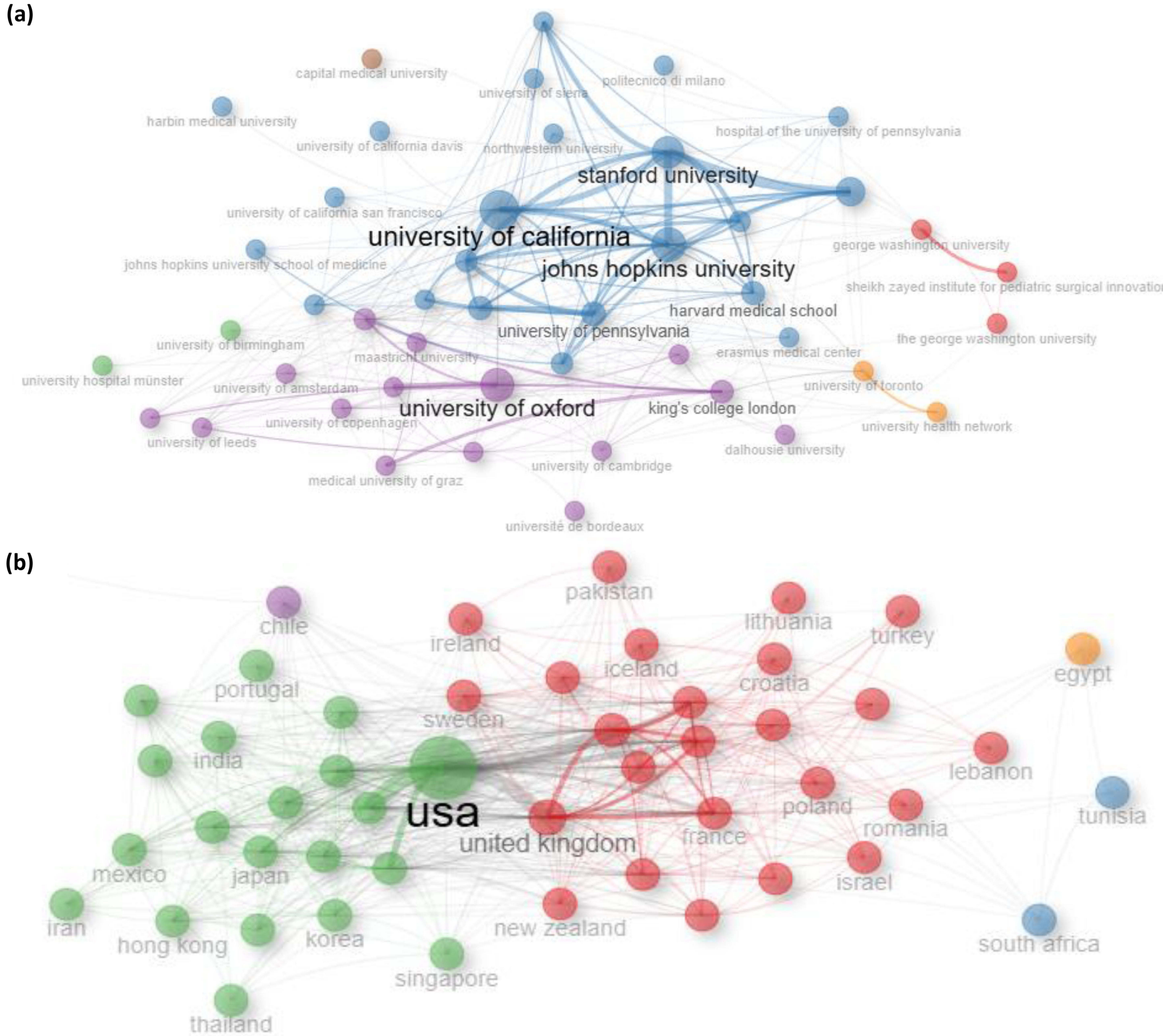

Figure 4 International collaboration networks in CEP. (**a**) Institutional-level networks, highlighting the University of California, University of Oxford, and Johns Hopkins University as central hubs. (**b**) Country-level networks, with the United States forming the largest cluster of collaborations with Europe and Asia. Line thickness indicates strength of co-authorship ties; node size represents number of publications. Note the absence of strong connections with African and Latin American countries.

low- and lower-middle-income countries contributed <3% of records and almost none in Q1 journals. These findings corroborate earlier alarms about "electrocardiographic deserts" in resource-constrained settings, where arrhythmic disease burden is often highest. Without targeted capacity-building and more inclusive editorial policies, disparities in both evidence generation and clinical outcomes will likely persist.[20]

These disparities carry important implications for low-resource regions. Beyond limiting local scientific visibility, underrepresentation restricts the generation of context-specific knowledge needed to address regionally prevalent conditions such as Chagas cardiomyopathy or rheumatic atrial fibrillation. Addressing this requires targeted capacity-building programs, equitable funding streams, and editorial policies that reduce barriers for authors in low- and middle-income countries. Strengthening regional centers of excellence and fostering both north–south and south–south collaborations could play a decisive role in narrowing these gaps and ensuring more inclusive knowledge production.

Heart Rhythm journal emerged as the most prolific outlet, whereas Circulation Research journal amassed the greatest citation count and highest h-index. This bifurcation between productivity and influence suggests that specialized journals drive topic penetration while broad-reach cardiovascular titles shape canonical knowledge. However, it is important to interpret these results with caution. Citation-based indicators are not neutral measures of scientific quality; rather, they

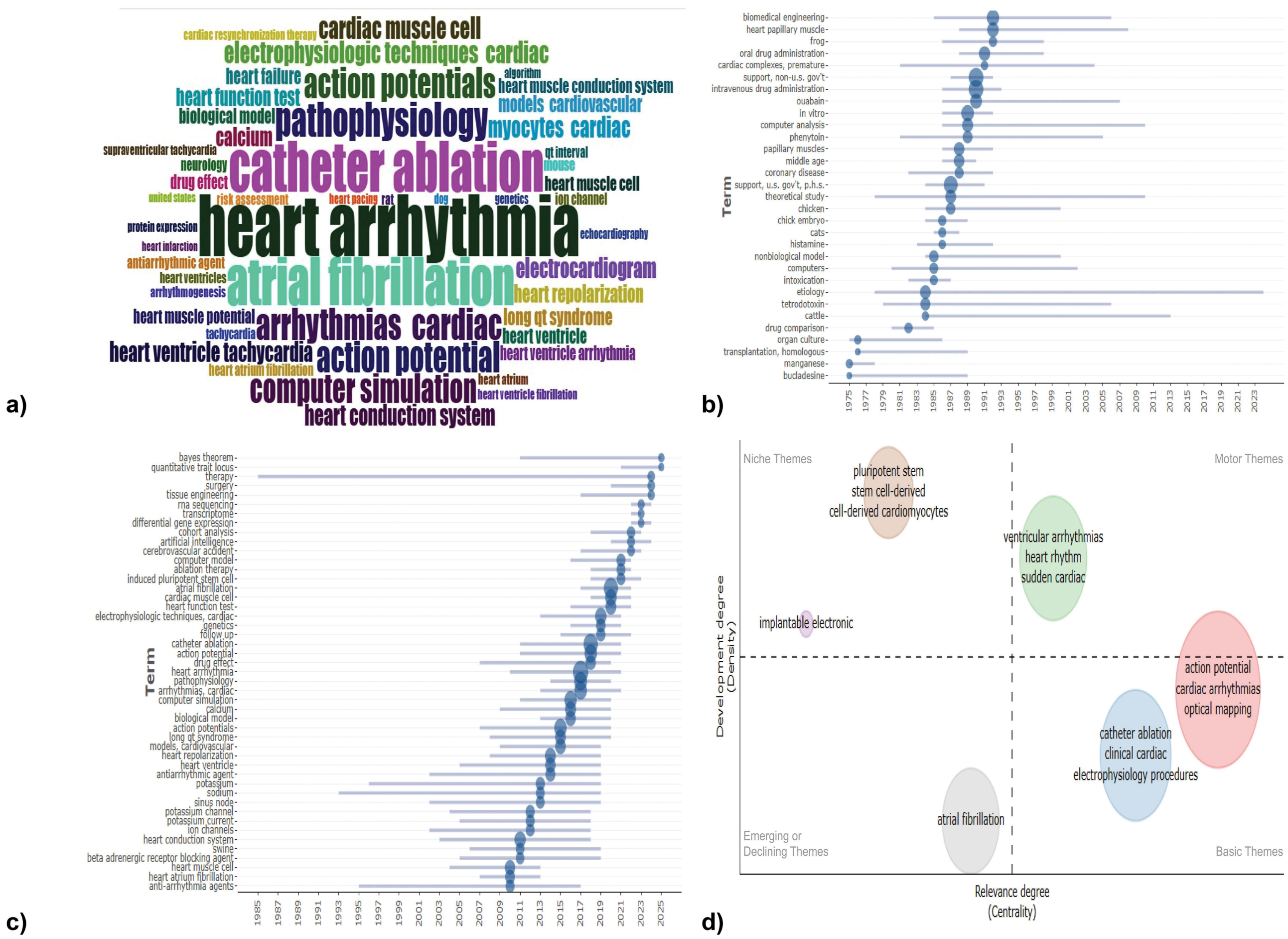

Figure 5 Historical trends in research topics and emerging themes in CEP. (**a**) Most frequently used keywords. (**b**) Early-stage research topics (1960–1990), dominated by pharmacological and in-vitro studies. (**c**) Contemporary topics (2000–2024), including arrhythmia, ablation, and induced pluripotent stem cells. (**d**) Thematic map showing implantable devices, atrial fibrillation, and stem-cell cardiomyocytes as well-developed clusters, while artificial intelligence and smart sensors remain emerging niches.

can be amplified by structural biases such as preferential indexing of English-language journals, higher visibility of certain outlets, and unequal access to research infrastructures across regions. Acknowledging these limitations prevents misinterpretation of citation density as a direct reflection of research excellence.

Notably, nearly 60% of articles appeared in Q1 journals, reflecting strong field visibility. Yet the steep drop-off in Q3–Q4 publications in high-income countries versus the flatter distribution in upper- and lower-middle-income settings hints at a two-tier system in which authors from emerging economies must often settle for lower-impact venues.[21] Our data therefore provide quantitative support for initiatives that waive article-processing charges or promote mentorship programs aimed at elevating manuscript quality from under-represented regions.[22]

Network mapping highlights the University of California system as the global fulcrum of institutional collaboration, with the United States forming the central hub at the country level. Partnerships cluster along traditional trans-Atlantic and trans-Pacific axes, whereas Latin America and, more conspicuously, Africa remain peripheral. The absence of South–South linkages deprives lower-resource regions of shared solutions to context-specific arrhythmic challenges such as Chagas cardiomyopathy or rheumatic-heart-disease-related atrial fibrillation.[23] Encouragingly, our data show that international co-authorship correlates with higher citation impact, validating policies that incentivize cross-border consortia and suggesting that modest investments in networking could yield disproportionate scientific returns.[24]

Keyword mining illustrates a historical migration from pharmacological studies (eg, ouabain and quinidine) and in-vitro biophysics (1960–1990) towards catheter-based ablation, device therapy, and large-scale genomic interrogation after 2000. Over the past decade, terms such as "induced pluripotent stem cell", "Bayes theorem", and "quantitative trait locus" have risen sharply, signaling a convergence of cellular reprogramming, probabilistic modelling, and precision electrophysiology. Our thematic map flags implantable electronic devices, induced pluripotent stem cells -derived cardiomyocytes, and atrial fibrillation as both well-developed and high-priority domains, whereas smart-sensor diagnostics and artificial intelligence-assisted risk stratification occupy an emerging quadrant with high growth potential but limited consolidation.[25,26] By quantifying these trajectories, the present study equips stakeholders to anticipate skill-set requirements and funding priorities for the next research cycle.

By delivering the first longitudinal, multi-database scientometrics portrait of CEP, this study transforms anecdotal impressions into actionable evidence. It reveals where capacity-building is most needed, which thematic niches are ripest for disruptive innovation, and how collaborative structures influence scientific visibility. The resulting knowledge map thus serves as a strategic compass for investigators, institutions, and policy makers intent on accelerating discovery, fostering equity, and ultimately improving arrhythmia care worldwide.[8]

A further limitation of our study is the reliance on citation-based metrics such as h-, g-, and m-indices. These indicators, while useful for quantifying scholarly influence, are also shaped by structural factors including journal visibility, language of publication, and regional accessibility. Therefore, citation density should not be interpreted as a pure proxy for research quality but rather as an indicator influenced by both academic merit and systemic inequities in global publishing.

Another limitation arises from potential database indexing bias across decades. Earlier years of cardiac electrophysiology research were less comprehensively indexed, which may have led to underrepresentation of older studies. Conversely, recent decades benefit from broader coverage as databases expanded. By triangulating three major repositories (Scopus, Web of Science, and PubMed), we mitigated but could not fully eliminate this source of bias. Therefore, temporal comparisons should be interpreted with this consideration in mind.

Regional disparities in access to journals may further influence citation density. Authors based in high-income countries generally benefit from broader institutional subscriptions and greater visibility in global networks, which enhances both their ability to publish in high-impact outlets and to be cited by peers. Conversely, limited access in low- and middle-income settings can reduce visibility and perpetuate structural inequities in citation patterns. These systemic differences should be considered when interpreting citation-based measures.

Gaps and Opportunities

Three critical gaps surface. First, geographic inequity: low-resource regions contribute minimally to the evidence base despite bearing a considerable arrhythmic burden. Addressing this requires network grants that pair high-income centers with institutions in underserved areas and journals that actively recruit submissions reflecting unique regional pathologies. Second, translational lag: the slow migration of cellular discoveries (eg, channelopathies in induced pluripotent stem cells models) into population-scale trials highlights a disconnect between mechanistic and clinical research streams. Multiphase funding mechanisms that mandate bench-to-bedside milestones could accelerate this pipeline. Third, data integration: although artificial intelligence and big-data approaches are emerging,[27] heterogeneous data silos hamper reproducibility and external validation. Standardized, open-access registries and federated analytics would promote broader participation and more generalizable findings.

This results partially bridge these gaps by: A) documenting the precise magnitude of regional under-representation, thereby furnishing quantitative targets for policy interventions; B) demonstrating the citation premium associated with diverse, multicenter collaborations, offering a persuasive argument for inclusive consortia; and C) delineating nascent thematic clusters that can guide informed investment in training and infrastructure. This information is valuable for future analyses related to meta-science and the education of future health professionals, who have the potential to contribute to this discipline.[28–32]

Conclusions

This six-decade scientometrics portrait of CEP offers researchers a practical roadmap for shaping the next wave of studies. First, the field is geographically imbalanced: almost 90% of publications and most high-impact papers come from high-income countries, while regions with growing arrhythmic burdens, Latin America, Africa and parts of Asia, remain under-represented. Positioning proposals around local pathologies such as Chagas-related cardiomyopathy or rheumatic-heart atrial fibrillation, and embedding them in north–south "twin-lab" partnerships, directly addresses this gap and leverages the citation and funding premium we observed for cross-regional teams.

Addressing these disparities requires concrete strategies such as capacity-building initiatives to strengthen research infrastructure in underrepresented regions, dedicated funding streams that incentivize collaboration with low- and middle-income countries, and editorial policies that actively encourage geographic diversity in published work.

Second, collaboration clearly pays. Articles that link basic-science groups (ion-channel biophysics, induced pluripotent stem cells models) with high-volume clinical ablation centers attract the most citations and Q1 placements, signaling that journals and grant panels value translational breadth over isolated excellence. Building multicenter consortia therefore increases both scientific influence and funding competitiveness.

The citation advantage of international collaborations likely stems not only from wider reach but also from the integration of complementary expertise, the ability to tackle region-specific arrhythmic challenges, and enhanced visibility through multinational dissemination. These features highlight why building equitable, cross-regional partnerships is critical for both scientific impact and translational relevance.

Third, the keyword trajectories pinpoint three high-growth yet under-populated themes: sensor-rich implantable devices, artificial intelligence-driven risk stratification, and stem cell–based disease modelling. Projects that fuse continuous device data with machine-learning algorithms, or that validate induced pluripotent stem cells discoveries in patient cohorts, sit squarely at this emerging frontier.

By aligning future studies with these geographic, collaborative and thematic insights, investigators can close persistent knowledge gaps, attract strategic partners, and place their work at the leading edge of CEP research.

Data Sharing Statement

Additional data are available from the corresponding author upon reasonable request.

Acknowledgments

We thank Dr. Ivan David Lozada Martinez (Universidad de la Costa, Barranquilla, Colombia) for his conceptual, methodological and statistical guidance.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Costantini O. Basic Principles of Cardiac Electrophysiology. *Med Clin North Am*. 2019;103(5):767–774. doi:10.1016/j.mcna.2019.04.002
2. Steinberg BA, Li Z, O'Brien EC, et al. Atrial fibrillation burden and heart failure: data from 39,710 individuals with cardiac implanted electronic devices. *Heart Rhythm*. 2021;18(5):709–716. doi:10.1016/j.hrthm.2021.01.021
3. Piccini JP, Russo AM, Sharma PS, et al. Advances in Cardiac Electrophysiology. *Circ Arrhythm Electrophysiol*. 2022;15(12):e009911. doi:10.1161/CIRCEP.121.009911
4. Sorgente A. Seeking Better Understanding of Cardiac Arrhythmias and Discovery of Novel Electrophysiological Therapeutic Targets. *JACC Case Rep*. 2021;3(3):530–531. doi:10.1016/j.jaccas.2021.02.003

5. Coronel R. The Future of Physiology: cardiac Electrophysiology. *Front Physiol*. 2020;11:854. doi:10.3389/fphys.2020.00854
6. Muresan L, Cismaru G, Martins RP, et al. Recommendations for the use of electrophysiological study: update 2018. *Hellenic J Cardiol*. 2019;60 (2):82–100. doi:10.1016/j.hjc.2018.09.002
7. Masic I. Scientometric analysis: a technical need for medical science researchers either as authors or as peer reviewers. *J Res Pharm Pract*. 2016;5 (1):1–6. doi:10.4103/2279-042X.176562
8. Lozada-Martinez ID, Lozada-Martinez LM, Fiorillo-Moreno O. Leiden manifesto and evidence-based research: are the appropriate standards being used for the correct evaluation of pluralism, gaps and relevance in medical research? *J R Coll Physicians Edinb*. 2024;54(1):4–6. doi:10.1177/14782715241227991
9. Lozada-Martinez ID, Neira-Rodado D, Martinez-Guevara D, Cruz-Soto HS, Sanchez-Echeverry MP, Liscano Y. Why is it important to implement meta-research in universities and institutes with medical research activities? *Front Res Metr Anal*. 2025;10:1497280. doi:10.3389/frma.2025.1497280
10. Lozada-Martinez ID, Fiorillo-Moreno O, Hernández-Paez DA, Bermúdez V. Clinical trials on medical errors need to strengthen geographical representation, methodological and reporting quality. *QJM*. 2025;hcaf068. doi:10.1093/qjmed/hcaf068
11. Khokhlov AN. How Scientometrics Became the Most Important Science for Researchers of All Specialties. *Moscow Univ Biol Sci Bull*. 2020;75 (4):159–163. doi:10.3103/S0096392520040057
12. Falagas ME, Pitsouni EI, Malietzis GA, Pappas G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. *FASEB J*. 2008;22(2):338–342. doi:10.1096/fj.07-9492LSF
13. Lozada-Martinez ID, Diazgranados-Garcia MC, Castelblanco-Toro S, Anaya JM. Global Research on Centenarians: a Historical and Comprehensive Bibliometric Analysis from 1887 to 2023. *Ann Geriatr Med Res*. 2024;28(2):144–155. doi:10.4235/agmr.24.0043
14. Lozada-Martinez ID, Lozada-Martinez LM, Cabarcas-Martinez A, et al. Historical evolution of cancer genomics research in Latin America: a comprehensive visual and bibliometric analysis until 2023. *Front Genet*. 2024;15:1327243. doi:10.3389/fgene.2024.1327243
15. Aria M, Cuccurullo C. Bibliometrix: an R-tool for comprehensive science mapping analysis. *J Informetr*. 2017;11(4):959–975. doi:10.1016/j.joi.2017.08.007
16. The World Bank. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed Sep 22, 2025.
17. World Health Organization. Countries/areas by WHO region [Internet]. 2025. Available from: https://apps.who.int/violence-info/Countries%20and%20areas%20by%20WHO%20region%20-%2012bfe12.pdf. Accessed Sep 22, 2025.
18. Rousseau R, Egghe L, Guns R. *Becoming Metric-Wise: A Bibliometric Guide for Researchers*. 1st edn ed. Belgium: Chandos Publishing; 2018.
19. Impact beyond citations. *Nat Biomed Eng*. 2018;2(1):1. doi:10.1038/s41551-018-0189-y
20. Nature Editorial. End the glaring inequity in international science collaborations. *Nature*. 2023;624(7992):473. doi:10.1038/d41586-023-04022-1
21. Gomez CJ, Herman AC, Parigi P. Leading countries in global science increasingly receive more citations than other countries doing similar research. *Nat Hum Behav*. 2022;6(7):919–929. doi:10.1038/s41562-022-01351-5
22. Else H. Open access is working - but researchers in lower-income countries enjoy fewer benefits. *Nature*. 2024. doi:10.1038/d41586-024-01748-4
23. Mocumbi AO. Cardiovascular Health Care in Low- and Middle-Income Countries. *Circulation*. 2024;149(8):557–559. doi:10.1161/CIRCULATIONAHA.123.065717
24. Trauernicht C, Court L. The value of global collaborations. *J Appl Clin Med Phys*. 2024;25(4):e14334. doi:10.1002/acm2.14334
25. Sánchez de la Nava AM, Gómez-Cid L, Ríos-Muñoz GR, et al. Cardiovascular Diseases in the Digital Health Era: a Translational Approach from the Lab to the Clinic. *BioTech*. 2022;11(3):23. doi:10.3390/biotech11030023
26. Zhang B, Schmidlin T. Recent advances in cardiovascular disease research driven by metabolomics technologies in the context of systems biology. *Npj Metab Health Dis*. 2024;2(1):25. doi:10.1038/s44324-024-00028-z
27. Picón-Jaimes YA. Innovation and Digital Transformation in Health Education: opportunities to Drive Technological Development in the Training of Future Professionals. *IngeCUC*. 2024;20(2):1–7. doi:10.17981/ingecuc.20.2.2024.10
28. Lozada-Martinez ID, Ealo-Cardona CI, Marrugo-Ortiz AC, Picón-Jaimes YA, Cabrera-Vargas LF, Narvaez-Rojas AR. Meta-research studies in surgery: a field that should be encouraged to assess and improve the quality of surgical evidence. *Int J Surg*. 2023;109(6):1823–1824. doi:10.1097/JS9.0000000000000422
29. Miranda-Pacheco JA, De Santis-Tamara SA, Parra-Pinzón SL, González-Monterroza JJ, Lozada-Martínez ID. Medical interest groups and work policies as emerging determinants of a successful career: a student perspective - Correspondence. *Int J Surg*. 2021;92:106020. doi:10.1016/j.ijsu.2021.106020
30. Ortega-Sierra MG, Beltran-Hoyos GE, Benjumea-Velásquez AM, Bossio-Martínez IM, Lozada-Martínez ID. Letter Regarding: surgery Interest Groups in Medical Schools: mentoring Factory. *J Surg Res*. 2021;267:209–210. doi:10.1016/j.jss.2021.04.045
31. Pérez-Fontalvo NM, De Arco-Aragón MA, Jimenez-García JDC, Lozada-Martinez ID. Molecular and computational research in low- and middle-income countries: development is close at hand. *J Taibah Univ Med Sci*. 2021;16(6):948–949. doi:10.1016/j.jtumed.2021.06.010
32. Silva-Rued ML, Ramírez-Romero A, Guerra-Maestre LR, Forero-Hollmann ÁM, Lozada-Martínez ID. The need to develop specialized surgical centers: the evidence that surgical diseases cannot wait. *Int J Surg*. 2021;92:106036. doi:10.1016/j.ijsu.2021.106036